Sains Malaysiana 36(2)(2007): 159-163

An Integrated Geophysical Study of the Quaternary Basin at Olak Lempit – Banting Area, Selangor, Malaysia

(Kajian Geofizik Bersepadu Lembangan Kuaterneri di Kawasan Olak Lempit – Banting, Selangor, Malaysia)

ABDUL RAHIM SAMSUDIN, UMAR HAMZAH & ZURAIDAH RAMLI

ABSTRACT

An integrated geophysical study was conducted to investigate the subsurface regional structure and the presence of a Quaternary sedimentary basin in the Olak Lempit - Banting area of Selangor, Malaysia. A regional gravity survey and the high resolution reflection seismic were employed to determine the thickness and areal distribution of the alluvial sedimentary basin as well as to investigate the depth and topography of the bedrock in the study area. The sedimentary basin hosts one of the most important coastal alluvial aquifer which was used to cater the shortage of domestic water supply during the worst water crisis that hit the state of Selangor in 1998. The surface geological map shows that in general 70% of the study area is covered by Quaternary deposits of Beruas, Gula and Simpang Formations which overlie the sedimentary bedrock of Kenny Hill Formation. The Beruas Formation consists of mainly clay, sandy clay and peat of Holocene fluviatile-estuarine deposits, whereas the Gula Formation represents Holocene marine to estuarine sediments which mostly consists of clay and minor sand. The Simpang Formation (Pleistocene) is a continental deposit comprising of gravel, sand, clay and silt. The underlying Kenny Hill Formation consists of a monotonous sequence of interbedded shales, mudstones and sandstones. The rock is Carbonaceous in age and it forms an undulating surface topography in the eastern part of the study area. A total of 121 gravity stations were established using a La Coste & Romberg gravity meter and the elevations of most of the stations were determined barometrically using Tiernan-Wallace altimeters. The high resolution seismic reflection using the common mid point (CMP) or roll along technique was carried out using a 24 channel signal enhancement seismograph and high frequency geophones. A total length of about 1.7 km stacked seismic section has been acquired in this survey and a nearby borehole data was used for interpretation. A relative Bouguer anomaly map shows an elongated zone of low gravity anomaly trending approximately NW-SE which is interpreted to be the deposition center of the Quaternary basin. The interpreted gravity profiles running across the central area of the study area show that the basin has thickness varies from tenth to several hundred meters with maximum depth to bedrock of about 275 m. A gravity profile which passes through the eastern edge of the basin was modeled with depth to bedrock of about 178 m below ground which agrees very well with those obtained from the interpreted seicmic section and borehole data. The stacked seismic section shows several high amplitude parallel to sub-parallel reflection overlying discontinuos and low reflection pattern. Reflections on the eastern part of the section is much shallower than the one observed on the western part which clearly indicates the presence of basinal structure with a total interpreted depth to bedrock of about 200 meters.

Keywords: Quaternary basin; seismic section; gravity modeling; subsurface structure

ABSTRAK

Penyiasatan geofizik bersepadu telah dijalankan untuk mengkaji struktur rantau bawah permukaan dan kewujudan lembangan sedimen Kuaterneri di kawasan Olak Lempit – Banting Selangor, Malaysia. Survei graviti rantau dan seismos pantulan beresolusi tinggi telah digunakan untuk menentukan ketebalan dan keluasan lembangan sedimen aluvium serta mengkaji kedalaman dan topografi batuan dasar di kawasan kajian. Lembangan sedimen ini merupakan akuifer aluvium pantai penting yang digunakan untuk menampung bekalan air semasa berlakunya krisis air terburuk di negeri Selangor pada tahun 1998. Peta geologi menunjukkan kawasan kajian terdiri daripada 70% endapan aluvium kuaterneri daripada Formasi Beruas, Gula dan Simpang yang menindih batuan sedimen Formasi Kenny Hill. Formasi Beruas ini kebanyakannya merupakan lempung, lempung berpasir dan gambut daripada sedimen fluviatil-estuarin yang berusia Holosen, manakala Formasi Gula pula merupakan sedimen marin-estuarin yang kebanyakannya terdiri daripada lempung dan sedikit pasir. Formasi Simpang pula (berusia Pleistosen) merupakan endapan benua yang terdiri daripada gravel, pasir, lempung dan lodak. Batuan dasar Formasi Kenny Hill terbentuk daripada selang lapis batu syal, batu lumpur and batu pasir. Batuan ini berusia Karbon dan membentuk topografi bawah permukaan beralun di bahagian timur kawasan kajian. Sebanyak 121 stesen graviti telah diukur menggunakan meter graviti La Coste & Romberg dan ketinggian kebanyakan stesen ditentukan dengan menggunakan barometer Tiernan-Wallace. Survei seismos pantulan beresolusi

tinggi menggunakan kaedah titik tengah sepunya (CMP) atau kaedah anjakan kesisi telah dilakukan dengan menggunakan seismograf peningkatan isyarat 24 saluran dan geofon berfrekuensi tinggi. Sepanjang 1.7 km keratan seismos telah diperolehi dalam survei ini dan data lubang gerudi yang berhampiran telah digunakan untuk pentafsiran. Peta bouguer anomali relatif menunjukkan zon anomali graviti rendah yang membujur dengan arah kurang lebih baratlaut-tenggara yang ditafsirkan sebagai pusat pengendapan sedimen lembangan Kuarterner. Pentafsiran profil graviti yang memotong bahagian tengah kawasan kajian menunjukkan ketebalan sedimen berubah daripada puluhan ke ratusan meter tebal dengan kedalaman maksimum batuan dasar sekitar 275m. Profil graviti yang melalui bahagian tepi timur lembangan telah dimodelkan dengan kedalaman sekitar 178m dan sesuai dengan hasil tafsiran yang diperolehi daripada keratan seismos dan lubang gerudi. Keratan seismos timbunan menunjukkan ciri pantulan selari dan sub-selari berfrekuensi tinggi menindeh corak pantulan berfrekuensi rendah yang tidak kontinu. Pantulan di sebelah timur kelihatan lebih cetek berbanding pantulan disebelah barat kawasan kajian yang jelas menunjukkan kewujudan struktur lembangan dengan kedalaman tafsiran batuan dasar sekitar 200 meter.

Kata kunci: Lembangan Kuarterneri; keratan seismos; permodelan graviti; struktur bawah permukaan

INTRODUCTION

An integrated geophysical study was conducted to investigate the subsurface regional structure and the presence of a Quaternary sedimentary basin in the Olak Lempit - Banting area of Selangor, Malaysia. The basin hosts one of the most important coastal alluvial aquifer which was used to cater for the domestic water supply during the worst water crisis that hit the state of Selangor in 1998. Mineral and Geoscience department of Malaysia was specifically directed to explore the possibility of groundwater exploitation in the study area which at the time was extracted ground water on a relatively small scale at Megasteel complex which produced about 10,500m^3/ day (Geological Survey Department 1998). The department had constructed several paired boreholes in various sites within the area. The shallow boreholes tapped water from the upper 25 m layer of mostly clay while the deeper boreholes tapped water below the 25 m depth which are from the sandy and gravel layer (Md. Shahid Ayub 2001).

Previous regional gravity measurements have been made in this area by the department of Mineral and Geoscience Malaysia. The principal difference in the present survey is in the attempt to obtain a uniform areal coverage representing an average station spacing of about 1.5 to 2 km. Other geophysical surveys i.e. 2-D resistivity imaging and resistivity sounding as well as seismic refraction have also been conducted in this area by Nawawi et al. (2001), Ibrahim et al.(2001), Ibrahim et al. (2003a), Ibrahim et al. (2003b) and Wong (2000) respectively. The works however did not cover the whole study area and depth of bedrock was not clearly established.

This paper describes results of a regional gravity survey and the high resolution seismic profiling which were employed to study the thickness and areal distribution of the alluvial sedimentary basin as well as to investigate the depth and topography of the bedrock in the study area.

GEOLOGY

The geological map of the study area shows that in general 70% of the area is covered by the Quaternary deposits of Beruas, Gula and Simpang Formations which overlie the sedimentary bedrock of Kenny Hill Formation. The uppermost layer is Beruas Formation which mainly consists of clay, sandy clay and peat of Holocene fluviatile-estuarine deposits (Azhar Hussin 2001). The presence of organic materials in the formation and the subsequent decaying cause the discoloration of water and acidity of the surface and upper aquifer.

The underlying Gula Formation represents Holocene marine to estuarine sediments which mostly consists of clay and minor sand. The lower most alluvium unit is Simpang Formation. It consists of terrestrial Pleistocene deposit comprising of gravel, sand, clay and silt overlying the Kenny Hill Formation bedrock. The coarse to very coarse sand and gravel as the main component occurred at the base of the formation (Loh 1992).

The Kenny Hill formation consists of a monotonous sequence of interbedded shales, mudstones and sandstones. The rock is Carbonaceous in age and it forms an undulating surface topography in the eastern part of the study area.

GRAVITY SURVEY

The gravity measurements were conducted along the available roads with a La Coste Romberg model G467 gravity meter. The gravity station interval is about 1 to 2 kilometers. The stations were located at position easily identifiable on the topographic maps, such as road junctions, bench marks and stream crossings. The elevations of the stations were determined using altimeters and the single base system. Two sets each comprising two Wellace and Tiernan altimeters were used, one set located at a base station (BM 0955), and the other set used for the field measurements at each gravity station (Zuraida Ramli 2001). In order to reduce error in the height determination, where possible, stations were located at points of known height, such as benchmarks and sea level. The error in the elevation was 2 to 3 meters for the altimeter readings.

To ensure that the gravity data obtained are of high quality, stringent field procedures as described by Butler et al. (1983) were observed. The selected base station was used to monitor and correct the drift of the equipment. Bench marks wherever available were used as control stations in order to minimise the error of the elevations measured.

All together about 121 gravity stations were obtained. Drift, latitude, free-air and Bouguer corrections were applied to the gravity readings. Terrain correction was not applied since the topography of the area is generally flat. An average density of 1.8 g cm^{-3} was used for the Bouguer correction. This density was chosen to represent the alluvium.

The relative Bouguer gravity anomalies along the traverses were projected onto several profiles for modeling purposes. Two-dimensional subsurface geological models for the profiles were obtained using a commercially available 2-D gravity program (Magix Plus). The gravity anomalies give information on density variations within the earth. It is well known that an infinite (but bounded) number of mass distributions can give rise to the same observed anomaly. Thus the models are non-unique. This ambiguity however can be resolved by conducting other geophysical techniques such as deep reflection seismic as well as by correlation with subsurface geological information from available boreholes.

SEISMIC REFLECTION SURVEY

For this present study, a high resolution seismic reflection survey using the common mid point (CMP) or roll along technique was carried out (Umar Hamzah et. al. 2000). A 24-channel signal enhancement seismograph (Abem Mark III) with high frequency geophones were used in the survey. Emulex 150 explosives with electric detonators were used for generating seismic source. The offset shot during the survey was set at 50 meters and then moved at an interval of 10 meters with fixed geophone spacing of 5 meters. This configuration produced the 12-fold CMPs seismic section, which was conventionally processed to produce a migrated stacked seismic section. A total length of about 1.7 km stacked seismic record, which covers eastern part of the basin was acquired. Interpretation of the seismic section was conducted based on a nearby borehole data, which produced a subsurface geological section as shown in Figure 1.

RESULTS AND INTERPRETATION

GRAVITY ANOMALY

A relative Bouguer gravity contour map of the study area is shown in Figure 2. The map shows a prominent zone of low gravity anomaly (-10mgal), with an elongated shape trending approximately NW-SE, located at about 3 kilometers to the south of Banting Town. The gravity minimum is believed to be associated with the thickest low density Quaternary deposits in the area which is interpreted as the deposition center of the Quaternary basin. It is also noted that the gravity anomaly values decrease southwestwards away from Tanjong Duabelas. However, in the southwest area of the deposition center, the gravity values appear to increase towards the coastal zone, as indicated by +2 mgal contour line. The gravity result suggests that in the southwest direction, the depth of bedrock increases towards the deposition center and then its decreases towards the coast.

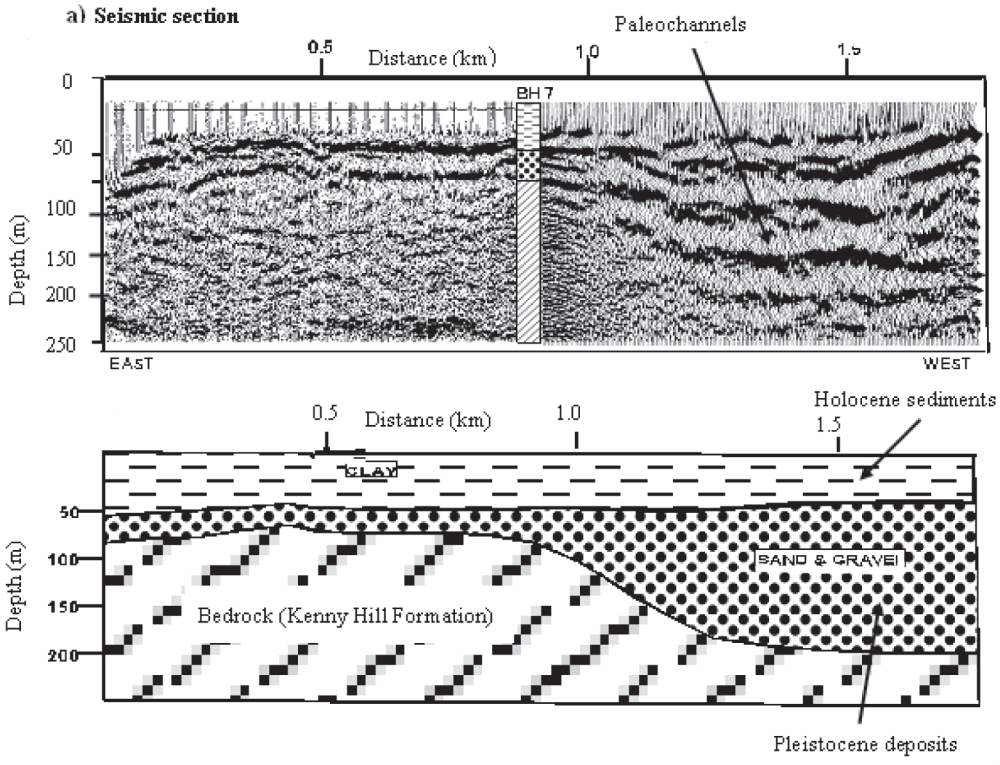

FIGURE 1. a) Seismic depth section showing distinct layers of the Quaternary Deposits and the paleochannel structure
b) Interpreted geologic section based on borehole and seismic data

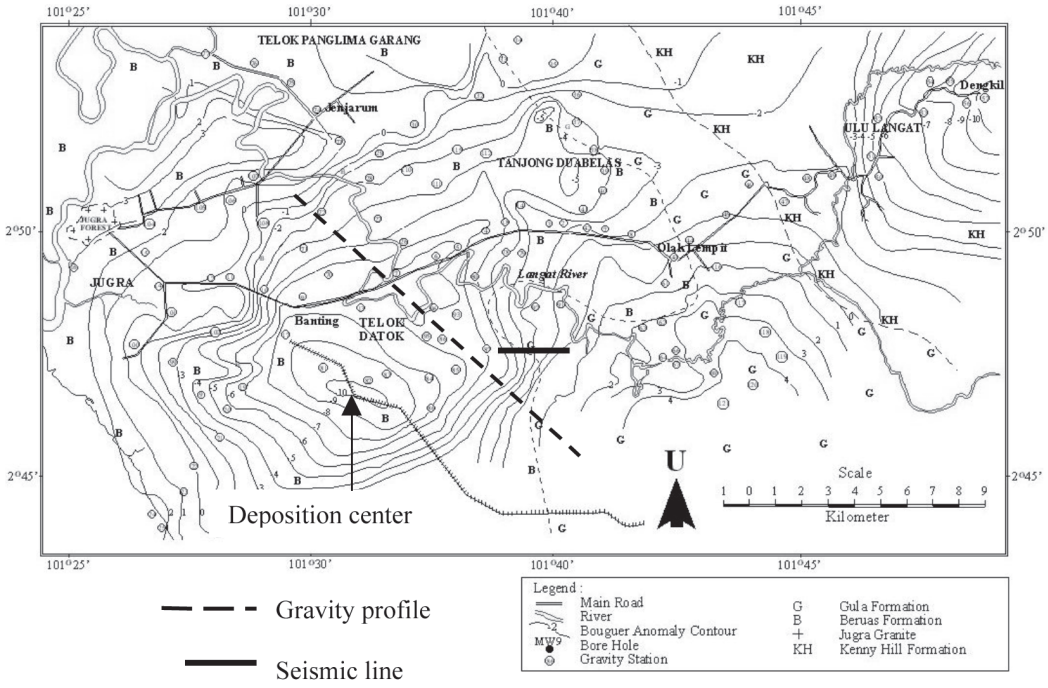

FIGURE 2. A relative Bouguer gravity map of Olak Lempit – Banting Area, Selangor

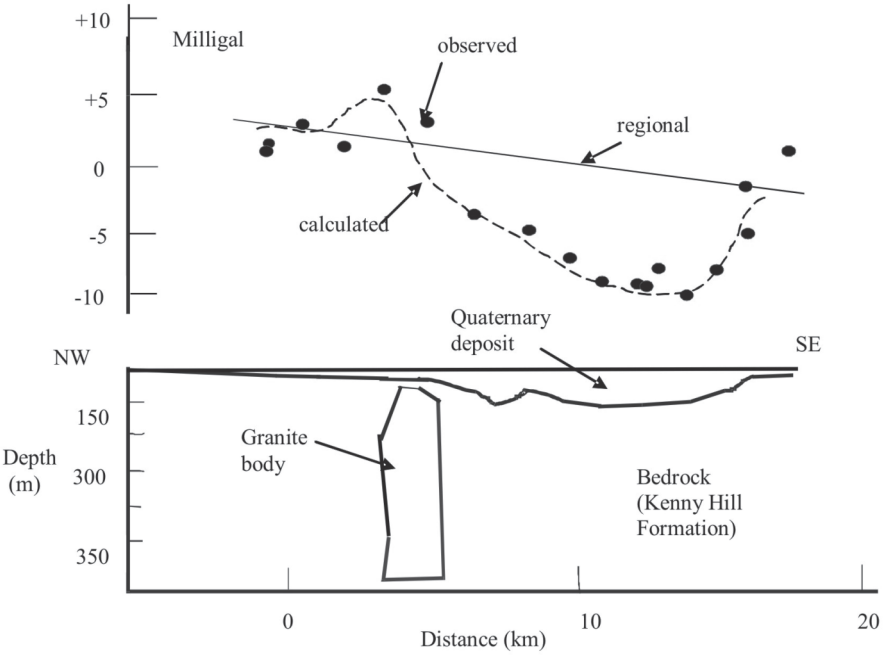

FIGURE 3: Gravity anomaly along NW-SE profile and its 2-D interpreted subsurface model showing a maximum depth of the basin is about 178 m

The interpreted gravity profiles running across the central area of the basin show that the thickness of the Quaternary deposits varies from tenth to several hundred meters with maximum depth to bedrock of about 278 m. A gravity profile (Figure 3) which passes through the northeastern edge of the deposition center of the basin was modeled with depth to bedrock of about 178 m below ground which agrees well with those obtained from the interpreted seismic section and borehole data.

SEISMIC SECTION

Figure 1a shows a stacked seismic section obtained in the eastern part of the basin. The seismic section shows several high amplitude parallel to sub-parallel reflection overlying discontinuous and low reflection pattern. Reflections on the eastern part of the section is much shallower than the one observed on the western part which clearly indicates the presence of basin structure with a total thickness of sediments of about 200 meters.

Figure 1a also shows the variation of the young sedimentary deposits from flat and slightly undulating layers on the eastern flank to a channel-like structure on the western flank. Total depth of the Quaternary sediments is calculated to be about 200 metres.

Seismic facies or reflection pattern on the eastern part of the section shows parallel to sub-parallel reflector on top overlying zone of free-reflection. In the western portion, the reflectors show high amplitude and sub-parallel to divergent seismic facies including a channel-like feature in the topmost part of the section. The length of the channel is approximately about 500 metres. Onlapping seismic features can be clearly seen below this paleochannel. The direction of the onlap is towards the east.

Deep monitoring well (BH7), which was drilled in the middle of the seismic section is used for the geological interpretation (Figure 1b). Depth shallower than 50 metres represents clay and sandy clay, while between 50 to 75m in the eastern and 50 to 200 m in the western part is filled up with sand and gravels. Underlying these sand and gravels is metasediment bedrock. Channel features in eastern side of the seismic section (Figure 1a) represent marine to estuarine deposits of Holocence Gula formation while the onlapping features from the deeper part of the section (western side) represent terrestrial Pleistocene deposits of Simpang Formation.

CONCLUSION

The gravity and seismic reflection surveys have been successfully used in this study to map the Quaternary deposits at the study area. The relative Bouguer anomaly map has enabled deposition center of the Quaternary basin to be located about 3 kilometers south of Banting town with a calculated sediment's thickness of more than 200 m. A follow up seismic reflection survey conducted near the eastern side of the deposition center confirms the existence of the Quaternary basin. The interpreted seismic section shows the occurrence of a depression with a thickness of approximately 200 meters deepening towards the western part of the survey line. However the thickness of the Quaternary deposit appears to be decreasing to the east.

The interpreted gravity profiles running across the central area of the basin show that the basin has thicknesses which varies from tenth to several hundred meters with maximum depth to bedrock of about 275 m. Both the seismic and gravity results appear to be in fairly good agreement.

ACKNOWLEDGEMENT

We would like to thank the member of UKM Geophysical Group for their cooperation in the geophysical field data collection and help in processing some of the seismic data. We also wish to thank the Department of Mineral and Geosains Malaysia for providing data used for the interpretation and the Malaysian Ministry of Sciences, Technology & Environment for financial assistance under RM7 IRPA project 02-02-02-0010.

REFERENCES

Azhar Hussin. 2001. General Geology of the Langat Basin. *The 2nd workshop on the study on the sustainable groundwater resources and environmental management for the Langat Basin, Malaysia,* 20th March 2001, Kuala Lumpur.

Butler, D.K., Whitten, C.B. & Smith, F.D. 1983. Cavity detection and delineation research-microgravimetric survey: Manatee springs site, Florida (Report 40. U.S. Army Engineer Waterways Experiment Station Technical Report GL-83-1 (Unpublished).

Geological Survey Department of Malaysia. 1998. Potensi air tanah di kawasan Teluk Datuk – Olak Lempit, Daerah Kuala Langat, Selangor, Internal Report No.- Laporan (Hidro) 01/98.

Ibrahim, A.N., Nawawi, M.M., Harith, Z. Z. T., Ayub M. S. & Alphonse, A. 2001. Ground water aquifer mapping using 2.5-D Electrical Imaging technique in Brookland Plantation, Selangor, Malaysia, *Prosiding Seminar Sehari Kemajuan Terkini Kaedah Geofizik Kejuruteraan,* Geological Society of Malaysia, 4.1- 4.7.

Ibrahim, A.N., Harith, Z. Z. T. & Nawawi, M.M. 2003a. Using integrated 2-D electrical imaging and seismic refraction methods for study of groundwater aquifer in Brookland Plantation, Selangor, Malaysia. *Proceeding of the 6th SEGJ International Symposium- Imaging Technilogy,* Tokyo, Japan, 398-404.

Ibrahim, A.N., Harith, Z. Z. T. & Nawawi, M.M. 2003b. Resistivity Imaging and borehole investigation of the Banting Area Aquifer, Selangor, Malaysia. *Journal of Environmental Hdrology.* V. 2, Paper 10.

Loh, C.H. 1992. Quaternary geology of the Teluk Intan Area, Perak. *Malaysia Geological Survey Quaternary Geology.* Bul. 3.

Md. Shahid Ayub 2001. *Isotpe Techniques in Hydrology: A case study in Olak Lempit, Selangor*, Seminar on Improving the management and protection of water resources in Malaysia, MINT, 1-8. Bangi, Selangor D.E.

Nawawi, M. N., Harith, Z. Z. T., Ayub, M. S., Ibrahim, A. N. & Alphonse, A. 2001. Modeling of an underground water aquifer using 2-D electrical imaging technique in Brooklands Plantation, Selangor, Malaysia. *Proceeding of the Second International Symposium on Geophysics*. 293 -297. Egypt: Tanta University Press.

Umar Hamzah, Abdul Rahim Samsudin, Abdul Rahman Yaacup, Rashid Bachik & Abdul Ghani Rafek. 2000. Penggunaan teknik geofizik dan geokimia untuk mencirikan struktur subpermukaan dan akuifer di sekitar Olak Lempit, Selangor, *Proceeding Annual Geological Conference 2000,* Geological Society of Malaysia: 381-386.

Wong, S.W. 2000. Kaedah geofizik dalam kajian endapan kuaterner lembangan Langat di sekitar Kuala Langat-Olak Lempit, B.Sc. (Hons.) Thesis SmSn. Bangi: Universiti Kebangsaan Malaysia.

Zuraida Ramli. 2001. Survei Graviti di Kawasan Olak Lempit - Banting, Selangor D.E., B.Sc. Hons. Thesis, Universiti Kebangsaan Malaysia (unpublished).

School of Environment and Natural Resource Sciences
Faculty of Science & Technology
Universiti Kebangsaan Malaysia
43600 UKM, Bangi, Selangor D.E.
Malaysia

Received: 1 March 2007
Accepted: 6 April 2007